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# Global policy of rural electrification

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ABSTRACT

Energy poverty and lack of electricity in the rural area exacerbate the poverty of the developing countries. The sustainable renewable technologies can be considered as efficient tools to reduce energy poverty whenever they are conducted based on an appropriate policy. Electricity can improve the human's lifestyle by increasing the level of health, education, welfare and technology. Currently, Sub-Sahara Africa with only 14.2% of rural electrification has the first rank in the world with lowest access to electricity, in that region around 585 million citizens has almost no access to electricity. The present study focuses on the general global policies to electrify the rural areas. In this regard, variety of plans and programs conducted by governmental and private institutes are investigated. In the year 2011, the International Energy Agency (IEA) has developed three global strategies based on the world energy market that defines the overall world energy approach. In the present work, different technologies for rural electrification are taken into account in two major categories of grid connected and off-grid systems. Furthermore, based on sustainable development with emphasis on environmental consideration, the feasibility of electrification by using different types of renewable energies such as solar, biomass, hydro, wind and wave have been studied. Despite reliability of grid connection, results indicate that renewable energy sources are the best choice especially in areas far from grid connections. Challenges between financial institutes and executive agencies result in resource management and technology development in order to overcome existing barriers and issues.



**Contents**



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## 1. Introduction

Rural area is defined as a region, which is not urbanized. One of the main characteristics of rural area is its low population density is one of the common highlights of rural areas. Normally high portions of the lands in rural areas are devoted to agriculture. On the other hand, there are vast arid regions around the world that are also considered as rural areas. Therefore, there is no unique definition of the rural area that can be applied to all regions in the world and it can be variable from each country to another. However, the most critical aspect in the rural area rather than low population density is less access to energy sources, lack of education, health, and welfares. Increasing access to affordable and reliable energy services is an approach to reduce the energy poverty in these regions. Electrification is one of the most promising services that can significantly affect decreasing energy poverty, improving life quality, reducing migration from the rural area to the towns and developing sustainable socioeconomic [1].

To enhance the living circumstances for people in rural areas, supplying electricity is obligatory. Some countries such as *Singapore* and *Thailand* have already met the target of 100% access to electricity for their residential regions [2]. However, in some developing countries there is still a long way to go, for instance, in *Bangladesh*, merely 32.5% of the inhabitants have access to electricity and many of them have to live in the remote parts of the country with no grid access [2]. According to the recent report from the International Energy Agency (IEA), over 1.3 billion people around the world have no access to electricity [3], almost 95% of these people are living in *Sub-Saharan Africa* and Asian developing countries. Fig. 1 shows the percentage of people that has no access to electricity in different countries around the word, almost 89% of these people are living in rural areas [3,4].

Based on the latest report of IEA, *Sub-Sahara Africa* with 14.2% rural electrification has the lowest access to electricity in the rural area whilst in terms of population without access to electricity, it has the first rank in the world with 585 million [3]. Table 1 shows

**Table 1**
Electricity access in 2009—regional aggregates [6].

| | Population without electricity (millions) | Electrification rate (%) | Urban electrification rate (%) | Rural electrification rate (%) |
|---|---|---|---|---|
| Africa | 587 | 41.8 | 68.8 | 25.0 |
| North Africa | 2 | 99.0 | 99.6 | 98.4 |
| Sub-Saharan Africa | 585 | 30.5 | 59.9 | 14.2 |
| Developing Asia | 675 | 81.0 | 94.0 | 73.2 |
| China & East Asia | 182 | 90.8 | 96.4 | 86.4 |
| South Asia | 493 | 68.5 | 89.5 | 59.9 |
| Latin America | 31 | 93.2 | 98.8 | 73.6 |
| Middle East | 21 | 89.0 | 98.5 | 71.8 |
| Developing countries | 1314 | 74.7 | 90.6 | 63.2 |
| World[a] | 1317 | 80.5 | 93.7 | 68.0 |

[a] World includes OECD and Eastern Europe/Eurasia.

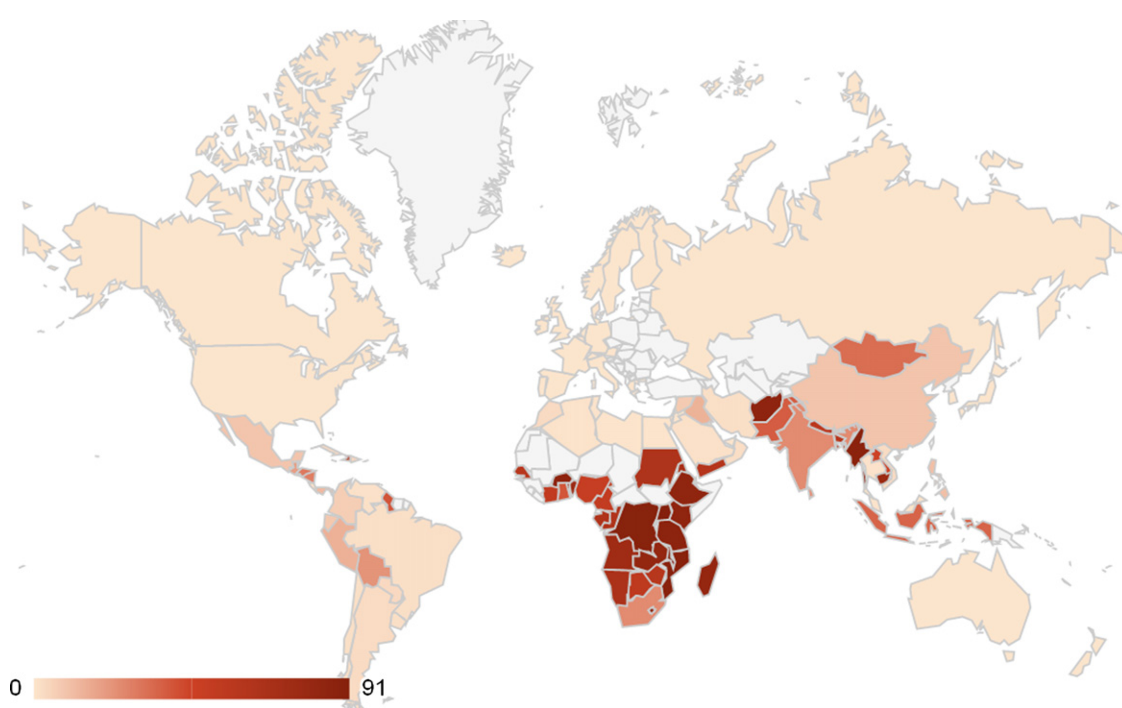


**Fig. 1.** Percentage of population with no access to electricity [5].

**Table 2**
Implemented policies to improve access to electricity services in different countries.

| Country | Typology of implemented policy | Achieved results or targets |
|---|---|---|
| Cambodia, Turkey, Vietnam, India, Taiwan, Nepal, Malaysia, Seri Lanka and Iran | Rural electrification based on different renewable energy sources along with other strategies(main policy) | Provide valid, affordable, and sufficient supply of electrical power for consumers, acquiring private and specific ownership of electrical facilities and persuading competition among the involved companies in energy sector |
| Bangladesh | US cooperative model, master plane, reducing tax | Efficient in preventing the probable fraud during the project via exploiting different anticorruption measures, improving electrification from rate of 29% (2004) to 50% and from 29% to 100% in 2020 |
| Brazil | Grid extension, some parts they have used renewable energy sources such as hydropower, Luz para Todos (light for all, LPT) which is based on low tariffs for low-income and rural customers | Electrification rate has reached up to 99.5% in urban areas and 88% in rural areas |
| Burundi | Hydro | 95% of power generation |
| China | Electrified by passed six phases, rural small hydropower plants, solar and wind energy | 95.5% of rural households had access to electricity by the end of this period |
| Ethiopia | Off-grid rural electrification | 12 projects which were implemented from 2006 to 2009, and 300 PV systems |
| France | Implementation of the national rural electrification program, electricity grid | By 2001, more than 90% of the whole country was electrified through grid electricity |
| Fiji | SHS system | Reducing the maintenance costs, overcoming tamper, reclining overexploitation of the system and correspondingly augmented the advantages |
| India | Renewable energy sources, "Rajiv Gandhi Grameen Vidyutikaran Yojana" Program | In 2009, the distribution of electricity in rural and urban population were 67% and 94%, providing over one hundred thousand electricity connection in rural area and electrifying more than 17 million rural households by March 2012, predicted that the rural and urban electrification will reach up to 84% and 98% in 2030 |
| Indonesia | Lending for grid solar power, national RE Master Plan, consolidating a viable financing plan for RE investments and recurrent costs, creating an effective institutional framework for rural electrification—the case for a strong central agency versus a more decentralized, codifying engineering and technical standards and design criteria, appropriate to local conditions and resource endowment | Achieving a high rate of economic growth and equitable distribution of income and social welfare, increase the electricity to 95% in 2025 |
| Iran | Renewable energy (hydro and geothermal, wind, solar) PV–wind–diesel–battery system | Less polluted air and lowered expenses, slowing down the rate of increasing in consumption of oil products |
| Kenya | Renewable energy mini-grids (biomass gasifiers or micro-hydro plants), rural electrification master plan, expanding access to electricity through both grid and off-grid systems | Potential energy poverty reducer tools, improving sustainable socio-economic in rural electrification, Electricity generation by hydro was reduced 18.4% by drought in 2008/09, reduce the population of those have no access to modern energy by 50% |
| Laos | Rural electrification project phase I (REP I) | Improved the electricity from 16% in 1995 to 63% in 2009, provide grid connected and off-grid electricity for 40,000 rural household during 4 years |
| Malaysia | Are the petroleum development act of 1974, given officially to PETRONAS (the oil and gas company of the state) and the national energy policy which was introduced in 1979, plan of improvement in economic progression | Supply, utilization, and environmental, increasing rural electrification from 67% in 1995 to 80% in 2000 and to 90% in 2005 in Sarawak state of Malaysia |
| Mozambique | Master plan (national grid, Cahora Bassa hydro dam) | Provide electricity for 20% of the residents with the grid electricity by the year |
| Mali | Off-grid system | Access electricity up to 7% in 2009 |
| Nepal | National 3-Year Interim Plan (main policy), supporting infrastructure and essential training, solar panels and hydro turbines (main technologies) | Increasing the electricity from 43.6% in 2009 to 100% in 2027, maintenance cost decreased and responsibility to service disruption improved, increase delivery efficiency in rural regions and subsequently to enhance the access of lower income households to electricity |
| Peru | Rural electrification plan (REP) and rural electrification law (REL), separate the private and public sectors, | Increased sharply from 57% in 1993 to 75% in 2002, decrease the operational costs |
| Philippine | Electrify by passed 5 phases, the demand side management (DSM) program, Philippines Energy Plan, 2004–2013 (main strategy) | Increase the capacity of rural electrification, promoting the efficiency of energy equipment and appliances, progression of energy service institutions and companies, electrify 90% of households by 2017 |
| Russian | Lenin's program and subsequent of Soviet-era plans, | Expansions of existing urban utilities, centralizing of regional stations and decentralizing rapid rural electrification, increase the required power from 218 GW in 2008 to 347 GW in 2020 |
| Rwanda | Establishing solar power plant in the rural area and developing off-grid system with micro-hydro systems, developing micro-hydro, solar, and methane-based solutions | Electrify 35% of population by 2020 |
| Scandinavian countries – Sweden and Norway | Use more renewable energy sources to reduce fossil fuel consumption | Some small-scale hydro-electric power stations |
| Senegal | Rural electrification priority program (REPP) | Increase electrification from 8% in 2003 to 62% by 2022 |
| South Africa | Integrated national electrification program | Providing electricity for 100% of population by 2020 |
| Spain | Renewable energy resources such as solar energy | Used electricity for households in short time period, in farmhouses |
| Sri Lanka | Biomass (major resource) | Making air less polluted and is to some extent a replacement for kerosene in urban and suburban areas |

**Table 2** (*continued*)

| Country | Typology of implemented policy | Achieved results or targets |
|---|---|---|
| Tanzania | Improve and expansion of grid electricity in rural areas and considering the decentralized systems | |
| Thailand | Grid electricity, the existing grid, accessibility by road, village size, number of expected customers in the first 5 years, potential agricultural and industrial electricity consumption, number of commercial establishments and the extent of public facilities, the government's commitment and national policy, electrification section in an institution in charge of distribution, an optimum plan to expand the system for the purpose of preventing financial overload, awareness and sufficient management of the financial situation | Over 99% of country and the rural areas are now electrified |
| Turkey | Build-own-operate (BOO) and build-own-transfer (BOT) | 12% of the energy consumption is provided through renewable sources |
| Uganda | International companies and fund | Improve the rural electrification |
| Vietnam | Stand-alone and household sized renewable energy technologies such as solar PV and wind generator | By the end of 2005, 95% communes or 88% households had access to electricity |
| Zambia | Grid expansion, SHS unit, mini-hydro, create the rural electrification authority (REA), master plan | Access to electricity up to 78% and 15% in urban and rural area by 2015 |

the number of population who has no access to electricity in the world.

Policy is typically described as a principle or rule to guide decisions and achieve rational outcomes. Policy is not normally used to denote what is actually done, this is normally referred to as either procedure. Most of the developing countries have implemented different policies to bring electricity in rural areas such as using renewable energies, ownership energy, power transmission, etc.

The focus of attention in this study is on those regions that are not linked to the national grid and the subsequent strategies and policies planned to be exerted. In this regard, various policies applied to electrifying rural area are investigated worldwide. The outcome is classified on country basis and various parameters such as successful and unsuccessful policies, utilized technologies, implemented projects and barriers and difficulties are taken into account.

### 1.1. The impact of electrification on rural area

Electricity can improve the human's lifestyle by increasing the level of health, education, welfare, and technology. In terms of poverty – as a multidimensional phenomenon – despite of facing with physical weakness, isolation, lack of access to knowledge, income, ignorance, and vulnerability, energy consumption is a way to distinguish the "poor" from the "non-poor". According to the analysis between survival, basic quality of life, social graces, and internal collaboration, annual electricity consumption of 1000 kW h per year per capita is known as the boundary between basic life condition and guaranteed survival [4].

### 1.2. Education and health

Normally, in rural areas children have to help their parents during the day, hence they can only attend to the classes during nighttimes which can only be done by presence of electricity. A survey in *Africa* shows a remarkable improvement in education level by improving the electrification network [7]. One of the major problems in the education field in rural areas is the minimum living facilities for educated staff to stay. Electricity as the most basic feature of life can motivate them to stay in the rural area that will consequently, increase the quality of schools and hospitals [8]. Electrification causes the hospitals to offer 24 h emergency services and improve equipment to enhance the level of health care services [7]. One of the other advantages of electrification is decreasing the harmful effects of burning fuels for cooking and lighting on the household's health [9]. Using electricity to pump the drinking water can significantly improve the health level by access to the safe and clean water [10,11].

### 1.3. Welfare

There are direct and indirect relationships between household welfare and energy consumption. By increasing the income of the households they will have more choices for their energy usage. At the same time, using modern electricity appliances such as lamps, electric cookers, television, refrigerators and air conditioning system bring obvious changes in household welfare [12]. The result of a study conducted in *Peru* [13] shows that the average household's welfare was extended due to electrification, in comparison with the conventional method of using limited diesel power system for few hours a day. The results also indicate that utilizing micro/mini-hydro grids can produce sustainable welfare benefits.

## 2. Policies and strategies required to support rural electrification

Countries around the world have each worked to improve access to electricity service. While many of the challenges faced by these countries are similar, the means of addressing them varied in their application and effectiveness. On the basis of our analysis, the implemented policies based on typology, targets, and results were briefly explained for different countries in Table 2. Thereafter, comprehensive explanations were taken into account to investigate the global and government policies around the world.

The world energy model (WEM) [6], which is provided by the IEA, is a principle tool that is used to generate details of how energy market operate sector-by-sector and region-by-region. In 2011, three scenarios named: current policies (CP) scenario, new policies (NP) scenario, and 450 scenario were presented by the IEA by using WEM. The CP scenario is a group of baseline policies, which are already adapted and implemented. On the other hand, introducing new measures to implement the broad policy commitment that has already been announced, including national pledges to reduce greenhouse gas emission and plans to phase out fossil fuels subsidies are the assumption of the NP scenario.

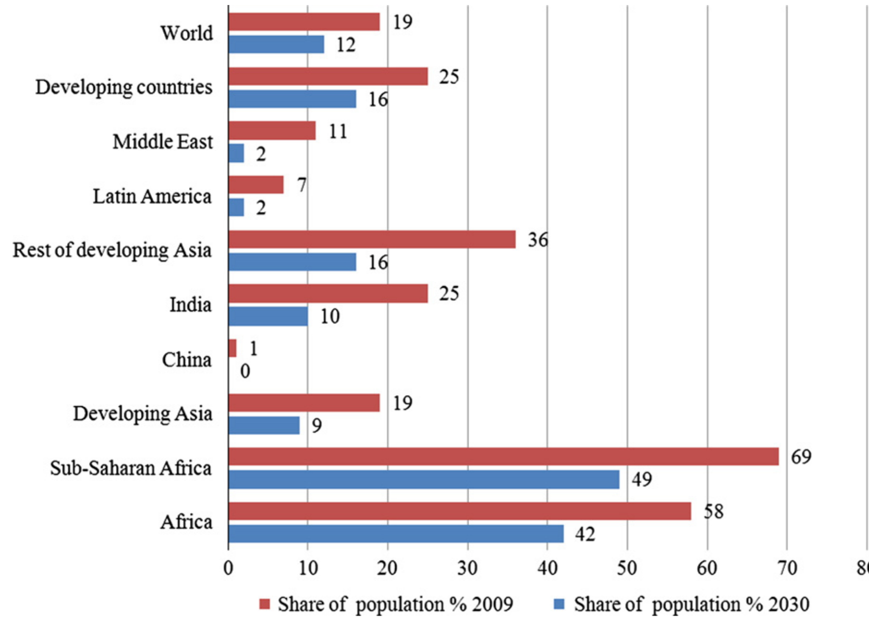


**Fig. 2.** Share of population without access to electricity by region in the new policies scenario.

The 450 scenario concentrates to prevent increasing the global average temperature more than 2 °C by limiting the concentration of carbon dioxide to around 450 ppm (PPM) in the atmosphere [6].

### 2.1. Global

The NP scenario is aimed to connect around 26 million people to electricity per annum from 2010 to 2030. Although the share of the global population lacking access to electricity declines from 19% from 2009 to 12% in 2030, still 1.0 billion people have no access to electricity by the end of the period. Fig. 2 presents the global effect of the NP scenario on some selected regions. Based on the data reported by the IEA, in 2009, the proportion of those without access to electricity in rural areas is almost five-times higher than those who live in urban areas, and this disparity is predicted to widen to be almost six-times higher in 2030 [3].

Despite common objectives like encouraging competition and increasing income, the motivation of electrification reform is quite different in developing countries. The World Bank (WB) has tried to increase efficiency, change the state electricity companies into business institutes, establish independent authorities, and transform the operation and maintenance activities to the private sector [1].

### 2.2. Government

There are numbers of policies that have been assigned by the governments themselves to overcome with the problem of lack of electrification in rural areas. For instance, the federal government of *Brazil*, starts to increase electricity connections in different parts of the country, from 1998. As a result, currently the electrification rate has reached up to 99.5% in urban areas and 88% in rural areas and most of the connections were held through grid extension while in some parts they have used renewable energy sources such as hydropower. Before that, in the early 1990s, most of the rural electrification policies were implemented at the state level. However, the new policy has been implemented with a goal of universal access in the rural area by 2010 that is called *Luz para Todos* (light for all, LPT) which is based on low tariffs for low-income and rural customers [14,15]. This program with the aims for full electrification started in 2003 and extended in 2011–2014. Up to now more than 2.4 million households are connected to the electricity [3].

In *Peru*, Rural electrification programs follow rural electrification plan (REP) and rural electrification law (REL) to bring the government into focus to solve electricity supply to the remote and rural area through directing rural electrification policy. After reforms in 1993, electrification increased sharply from 57% to 75% in 2002. REL was commenced to improve rural electrification rate and promote renewable energy [1].

Rural electrification policy needs to be modified in *Peru*. In this case the relationship between the private sector and the state, involve the private firms to rural electrification, and the role of local community in the decision-making process have to be considered [1]. One of the main problems of electrification is the total government budget. Government of *Peru* demonstrate that private and public sectors must be separate. On the other hand, a relationship between public and private sector as a public–private partnership is significant. Despite of separation of private and public sectors in electrification programs, based on government strategy, private sector involves with government policy. Using local communities to manage and contribute in investing in some projects have been missed [16,17]. In order to decrease the operational costs, strategy of using pre-pay meters was executed in *Adinelsa*, centralized government authority in *Peru*. Households not using pre-pay meter have to pay the cost of electricity without tariff, otherwise their electricity would be disconnected.

Supporting infrastructure and essential training were provided by the rural energy development program in *Nepal* and practical action in *Peru*, to improve the ability of managing off-grid electrification systems by local communities. As a result of encouraging communities by government to self-manage their system, theft in the community of *Mugling* (*Nepal*) was reduced by 20%, maintenance cost decreased and responsibility to service disruption improved [13]. The "National 3-Year Interim Plan" is the main policy of *Nepal* that focused on providing 100% access to electricity by the year 2027, from 43.6% in 2009 [3,18].

Rural electrification based on different renewable energy sources along with other strategies are the main policies of some Asian countries such as *Cambodia*, *Turkey*, *Vietnam*, *India*, *Taiwan*, *Nepal*, *Malaysia*, *Sri Lanka* and *Iran*. National policy of *Cambodia*

focuses to provide valid, affordable, and sufficient supply of electrical power for consumers. Progression of renewable energies is one of the approaches adapted to meet the objectives include acquiring private and specific ownership of electrical facilities and persuading competition among the involved companies in energy sector are the other objectives that are succeeded based on this policy [19,20].

In *Turkey*, 12% of the energy consumption is provided through renewable sources. It has early and thoroughly utilized financing models such as build-own-operate (BOO) and build-own-transfer (BOT). However, no decisive development has been accomplished. The sign of privatization has been introduced into the Turkish constitution for the first time. Legislation was adopted in February 2001 to allow competition in the electricity market and adapt Turkey's legislation for European Union (EU) membership. A new gas market law was adopted in May 2001 for the same purposes [21].

By the end of 2005, 95% communes or 88% households had access to electricity in *Vietnam*. Using stand-alone and household sized renewable energy technologies such as solar PV and wind generator are the solutions that this country was applied to improve electricity access for the rest of population [22].

Global policy approaches to reduce GHGs and the effect of fossil fuels on environment force many countries to turn to renewable energy sources. Number of Asian countries also tries to change their approach in this way. *India's* spread of different renewable resources has been developed by a variety of fiscal measures and so far 12 states are using renewable energy sources. However, the government is currently in the process of exerting concise renewable resources policy. Nonetheless, there are some problems regarding the realization of this policy such as cost and positive apprehension of renewable resources which society needs to attempt of people in saving the environment. According to Indian government information in 2009, the distribution of electricity in rural and urban population were 67% and 94%, respectively [23]. Despite of improving rural electrification in *India*, the average electricity consumption is 96 kW h per person per year in rural area vs. 288 kW h per person per year. in urban area. ''Rajiv Gandhi Grameen Vidyutikaran Yojana'' Program with a target of providing over one hundred thousand electricity connection in rural area and electrifying more than 17 million rural households by March 2012, is the famous project in *India*. It is predicted that the rural and urban electrification will reach up to 84% and 98% in 2030, respectively [3].

Solar panels and hydro turbines are the main technologies considered by the government of *Nepal*. The major purpose of this strategy is to increase delivery efficiency in rural regions and subsequently to enhance the access of lower income households to electricity. The policy of *Nepal* is far different from India in not only size and quality of the project, but also in physical conditions. Overall, financial analysis shows that the overall cost of implementation of micro-hydro (MH) system in remote area is lower in Nepal to compared with India and it is influenced by the geographical feature of the region [24].

Major rural electrification policies that federal government of *Malaysia* has taken into account are the petroleum development act of 1974, given officially to PETRONAS (the oil and gas company of the state) and the national energy policy which was introduced in 1979 with the initial objectives of guaranteeing sufficient and reliable energy supply sources, promoting efficient utilization of energy and reducing the harmful impact of energy production on the environment. The country's policy plans to achieve defined objectives through developing local energy resources both non-renewable and renewable energy resources, using the least-cost options and diversification of supply sources both from within and outside the country in order to ensure the provision of sufficient, secure and cost-efficient energy supplies, and encourage promoting renewable energy and enhancing energy efficiency to minimize the harmful impact of energy production, transportation, conversion, utilization and consumption on the environment [25–30]. Rural electrification under the plan of improvement in economic progression was enhanced from 67% in 1995 to 80% in 2000 and to 90% in 2005 in *Sarawak* state of *Malaysia* [31,32].

Achieving a high rate of economic growth and equitable distribution of income and social welfare are main objectives of rural electrification policy in *Indonesia*. Lending for grid solar power, such as solar home system (SHS), through WB for rural electrification of *Indonesia*, where power generation, transmission and distribution are face to difficulties, are considered [33]. Nowadays, 36% of Indonesian population has no access to electricity. The main policy in this country is to decrease it to 5% by 2025 [3]. In order to achieve the objectives, the following programs were considered: Undertake a comparative study of the Indonesian electricity tariff system with that of a country in Southeast Asia such as Thailand that has achieved high quality national electricity supply and high rates of electrification, develop and implement staged increases in electricity tariffs to achieve cost-reflective tariffs, establish a high level working group to rapidly develop a road map for the creation of an expert, independent and non-political electricity regulatory body, provide local governments and communities in rural areas with direct funding and more autonomy for their rural electrification programs, continuously monitor and evaluate the effectiveness of rural electrification programs to ensure that they achieve their maximum potential over the medium and long term [34].

Biomass as a kind of renewable energy source is a major rural electrification resource in *Sri Lanka*. Biomass is being used on account of making air less polluted and is to some extent a replacement for kerosene in urban and suburban areas [35,36].

The noteworthy feature of *Iran* in using renewable energy is that it makes use of all four renewable energies existed in nature subsequently, hydro and geothermal in northern and western regions, wind in eastern and southern, and solar in deserts locating mostly in the center [37]. Having less polluted air and lowered expenses would have been accessible if the government and state-run electrical provider had decided the PV–wind–diesel–battery system [38]. Through expanding access to cleaner energy (natural gas and electricity) has proven to be successful, at least in slowing down the rate of increasing in consumption of oil products. Nevertheless, price policies were not successful in adjusting energy prices with respect to the long-term (1978–2004) price index [39].

Rural electrification policy was applied in *Bangladesh* based on the US cooperative model, which was a successful project in rural America in 1930s. The plan was so efficient in preventing the probable fraud during the project via exploiting different anticorruption measures [40]. Government helped the system cost to be reduced by providing exemption for taxes in 1998 [2]. To reduce poverty trough electrifying two hypothetical scenarios are considered: improving electrification from rate of 29% (2004) to 50% and from 29% to 100%. Based on implementation of these two scenarios, 90% of rural households will be electrified by government. The mentioned scenarios will lead to 5.4% and 16.7% poverty reduction [12]. Latest information from IEA shows that 59% of population in *Bangladesh* are living without access to electricity. The country has adopted a ''master plan'' in which it is considered to provide electricity for all by the year 2020 [3].

*China*'s method of electrifying is more complicated in comparison with other countries since its government passed through six phases in order to reach the desired outcome of energy. In the interval between the first phase from 1915 and fourth phase in 1987,

the rural networks as well as rural small hydropower plants were encouraged to progress. Ultimately, the rate of energy consumption reached up to 30 kW h per capita per year at the end of this period that is around 13% of the countries demand. In fifth phase, started from 1988 and finished in 1997, rural electrification was developed through different programs such as solar and wind energy. As a result, 95.5% of rural households had access to electricity by the end of this period [41].

The government of *Philippine* considered the demand side management (DSM) program to increase the capacity of rural electrification. It includes five district phases: promoting the efficiency of energy equipment and appliances, establishing a DSM policy in ERB, progression of energy service institutions and companies, the continuity of the DSM's collaborative process, and a sufficient DSM financing and professional staff [42]. The main strategy of government (Philippines Energy Plan, 2004–2013) is to electrify 90% of households by 2017.

Household electrification in *Laos* was improved from 16% in 1995 to 63% in 2009. Rural electrification project phase I (REP I) is the latest government project to provide grid connected and off-grid electricity for 40,000 rural household during 4 years. The 'REP I' was financially supported by the WB, global environment facility and Norwegian agency for development cooperation. The reduction of poverty was introduced as the major aim of the government and the question posed was how to maximize the impact of poverty reduction. The economists proposed the utilization of economic analysis for making the priority for the areas which should get electrified [43].

*Russian* government in 1920 adopted electrification as a way to reach the top in the world economic, political and social reconstruction situation. Electrification was performed through three technological strategies expansions of existing urban utilities, centralizing of regional stations and decentralizing rapid rural electrification. Each strategy followed by different political, social, economic and technical implications. [44]. The *Russian* electricity system is largely a consequence of Lenin's program and subsequent of Soviet-era plans. *Russia*, as one of the largest market on the world, consumes 5% of global power consumption. Its government has designed a new strategy to increase the required power from 218 GW in 2008 to 347 GW in 2020. This amount is so hard to achieve, but government expected to do that by increasing the economic growth into 6.82% annually between 2013 and 2020. This, coupled with a decline in the population from 142 to 135 million will help government to cover this policy [45].

The last selected Asian country whose policy was something else rather than renewable energy is *Thailand*. The policy that government has taken to electrify the rural regions is grid electricity. Electrification of villages is ranked based on proximity to the existing grid, accessibility by road, village size, number of expected customers in the first 5 years, potential agricultural and industrial electricity consumption, number of commercial establishments and the extent of public facilities. As a result, over 99% of country and the rural areas are now electrified. There are definite effective reasons for which the government was able to electrify this percentage of the country such as: the government's commitment and national policy, electrification section in an institution in charge of distribution, an optimum plan to expand the system for the purpose of preventing financial overload, awareness and sufficient management of the financial situation, the development of a series of objectives criteria in order to ignore any political interference when selecting the villages and so many other reasons [46].

As a viewpoint of electrification, European countries were able to use more renewable energy sources to reduce fossil fuel consumption. The common considered policy by Scandinavian countries – *Sweden* and *Norway* – is to use water as a main source and some small-scale hydro-electric power stations were established based on this policy. In 1920s, most of the industrial centers and towns in *France* were electrified. However, 40% of the population still lived in non-electrified areas. By the third decade of this century, 70% of the rural resident was connected to the electricity grid by implementation of the national rural electrification program. The managerial and political responsibilities of the rural electrification program were by the director of rural electrification and the ministry of agriculture, respectively. By 2001, more than 90% of the whole country were electrified through grid electricity [46].

*Spain* like many other countries has been electrified by using renewable energy resources such as solar energy as well as using traditional way of electrification. There are some observations to assert the sustainability of solar energy in rural areas: first, encouraging end-users to utilize PV system by allocating subsidy. Second, choosing between traditional energy and solar (PV) depends largely on the temporal horizon. Hence, using solar energy would be more sensible for the households to be used if they want to use it for a short period of time, especially if they rent a house. Third, the activity exploited in farmhouses was mostly crucial. Indeed, the solar energy sounded more accurate in private households whose energy consumption was low [47].

The rural electrification of *Tanzania* was improved through two strategies: (a) improve and expansion of grid electricity in rural areas and (b) considering the decentralized systems [48–50]. Despite the annual increase of electrification, it is predicted that the share of the population with no access to electricity in *Sub-Saharan Africa* would increase by 10% in the year 2030 compared to 2009. On the other hand, in *South Africa*, the integrated national electrification program is the main strategy of electrification with the objective of providing electricity for 100% of population by 2020.

In *Rwanda*, several private and state companies are working to improvement rural electrification in various projects and with different approaches such as establishing solar power plant in the rural area and developing off-grid system with micro-hydro systems [51,52]. The target of government is to electrify 35% of population by 2020, by developing micro-hydro, solar, and methane-based solutions [51].

By the year 2003, 99.5% of rural and 80% of urban households had no access to electricity in *Kenya*. Renewable energy mini-grids powered by biomass gasifiers or micro-hydro plants were used as a potential energy poverty reducer tools [53]. Electricity generation by hydro was reduced 18.4% by drought in 2008/09 [13]. As a result, off-grid renewable energy sources were considered by the government of *Kenya*. Rural Electrification Agency (REA) with the aim of improving sustainable socio-economic in rural electrification was created in 2006. REA is mandated to be responsible for the following tasks: financial management of the rural electrification program, improve and update the rural electrification master plan, and expanding the use of renewable energy sources [54]. As a result of the millennium development goals, the policy of the government of Republic of *Kenya* is to reduce the population of those have no access to modern energy by 50%, and decrease the number of people who live in poverty up to 50% by 2015. This will be done by expanding access to electricity through both grid and off-grid systems and in collaboration with development partners, non-governmental organizations, and the private sector [55].

Unlike *Kenya*, the strategy that is used in the rural area in *Malawi* was different. Since, the majority of rural area were located to suburb and industrial factories, they are using the grid electricity for their village. The main aim was regarding to schools, hospitals, and some of the institute in the villages. The government policy was to prevent the rural residence migration

to the urban area. Therefore, most of the rural area have access to the grid electricity in *Malawi*.

*Zambia* is known as the country with the least access to electricity in the world, with only 2% access to electricity in 2005. So far, expanding rural electrification through expansion of the grid was not successful in this country. Therefore, rural electrification authority (REA) was created by the government of *Zambia* with an innovative approach to rural electrification [56]. They focus on policy making, strategy planning and development of rural electrification with the aim of improving access to reliable electricity for the rural resident since 2003. According to the latest information, around 74 grid extension projects were implemented since 2006 also around 92 SHS units were installed in 2008, numbers of mini-hydro project with 150 kW capacity are also supported financially [54,57]. Rural electrification master plan with objectives of increasing access to electricity up to 78% and 15% in urban and rural area, respectively by 2015 is the major plan for improving access to electricity [3].

Almost all of the electricity in *Mozambique* is produced by Cahora Bassa hydro dam and distributed by the national grid. In this country, a master plan with the aim of expanding the national grid and distributing networks is established by Electricidade de Mozambique (EDM) in 2004. The main purpose of this plan is to provide electricity for 20% of the residents with the grid electricity by the year [7,51].

According to the WB's report in 2010, only 35.9% of population in *Sudan* have access to electricity. Around 55% of the electricity is generated by hydropower and 45% is produced by thermal generation [18]. The "United States Agency for International Development" (USAID) has joined with the government of South Sudan to improve infrastructures such as electrification, water supply, roads and bridges. Building up electrification, through both infrastructure construction projects and technical assistance, begun in 2005 under USAID's southern Sudan rural electrification program (SSREP) with the fund of the national rural electric cooperative association (NRECA) [58]. The government of *Burkina Faso* only focuses on the hydro technology. All of the private companies and institutes that are working in rural electrification prepared infrastructure of the hydro system in rural area. An international company from Denmark is managing the financial issue of this project [59,60]. Electricity supply in *Mali* is limited to around 20% of the urban population and less than 7% of the rural population. According to the government's report, off-grid system has been developed to 7% in 2009 [61,62].

It is reported that only 30% of population in *Senegal* had access to electricity in 2007. The share of rural population who had access to electricity was about 12.5%. The government used a new program to maximize the number of rural household electrification with the contribution of public and private sector. Based on the rural electrification priority program (REPP) in 2003, the country is divided into 18 rural electrification concessions with about 30,000 household without access to electricity. The policy of *Senegal* is to increase electrification from 8% in 2003 to 62% by 2022 based on the aforementioned program [63].

### 2.3. Private institutions and local authorities

After privatization in *Peru*, around 15% of total foreign direct investment (around $1.15 billion) charged to the electricity sector during the 1990s. By the year 2011, around 65% of the electricity generation and 70% of its distribution were handled by private companies. Despite the influence of liberalization and privatization to improve the Peruvian electricity sector, the effect on rural area to deliver energy to the poor population was not sufficient [1].

Some policies for SHSs were realized via proposing the idea of social ownership by government of *Fiji*. Accordingly, the private ownership generates some benefits such as reducing the maintenance costs, overcoming tamper, reclining overexploitation of the system and correspondingly augmented the advantages [2].

The majority of populations of Burundi are living in the village (90% based on the data available in year 2002). The most important energy resource in the country is hydro with the share of 95% of power generation. This includes 24 national and regional micro hydropower plants (MHP) and 2 foreign SHPPs on the border. In case of hydropower failure, one diesel-based power plant with the capacity of 5.5 MW is provided [51].

The electrification rate in *Ethiopia* was around 17% by the year 2009 [18]. Rural electrification executive secretariat (REES) is in charge of Ethiopian rural electrification system (off-grid) and implementation and operation is done by the private sector or the community-based organizations. Twelve projects which were implemented from 2006 to 2009, and 300 PV systems for health post and primary schools which are under tendering stage can be named as the important off-grid rural electrification projects that were covered by REES [51].

Since 1985, the government of *Uganda* started to improve the rural electrification in partnership with international companies. The main aim was to generate and apply the modern technology in rural area [64,65]. Rural electrification agency and rural electrification fund provide some of the international funds in rural electrification field. Rural electrification board organization with the approach of providing renewable energy technology in rural area was established in 2002. Members of this company were from the ministry of electricity, private companies and private banks. Rural electrification agency provides subsidies to dedicate to renewable energy systems, especially solar devices like PV system [64–66].

## 3. Financial issues and financial assistance

In the NP scenario, around US$275 billion of investment is dedicated to provide electricity access from 2010 to 2030. This represents annual average investment of US$13 billion to connect around 26 million people per year. The average annual level of investment in electricity access increases by almost 45%, compared with that observed in 2009 [3]. According to the "energy for all cases" scenario, US$640 billion is required to achieve universal access to electricity for period of 20 years since 2010 (Table 3). The combination of different solutions such as: on-grid, mini-grid and isolated off-grid based on the regional costs and customer density are taken into account to identify the electricity providing option in each region. The regional cost per megawatt-hour of an established grid is cheaper than that of mini-grid or off-grid solutions. However, in sparely population area, remote or mountainous area, the cost of extending grid is high. Grid transmission between rural area, that is usually far from each other, include high cost and high technical losses. Therefore, despite of higher

**Table 3**
Additional investment required to achieve universal access to electricity in the Energy for All Case (billion in year-2010 dollars) [3].

| | | | |
|---|---|---|---|
| Africa | 119 | 271 | 390 |
| North Africa | 118 | 271 | 389 |
| Developing Asia | 119 | 122 | 241 |
| India | 62 | 73 | 135 |
| Rest of developing Asia | 58 | 49 | 107 |
| Latin America | 3 | 3 | 6 |
| Developing countries[a] | 243 | 398 | 641 |
| World | 243 | 398 | 641 |

[a] Developing countries total includes Middle East countries.

cost per MW h of stand-alone systems, 70% of rural areas are connected either with mini-grids or with small, standalone off-grid systems. The mentioned costs do not include the transmission and distribution costs. *Ethiopia*, *Nigeria*, and *Tanzania* use these solutions and more than 60% of the additional investment required is in *sub-Saharan* Africa to achieve universal access to electricity by 2030. This amount is around 38% in Developing Asia countries [3].

The highest share of additional investment (US$ 20 billion annually) in the "energy for all case" scenario is related to mini-grid and off-grid solutions. It is estimated that this amount increase from US$ 20 to 55 billion US$ per year toward 2030. This growth is parallel to increase of the number of additional connections that is augmenting from 25 to 80 million per year from 2010 to 2030. Table 4 briefly explains additional budget and number of access to electricity according to the Energy for All case scenario comparing with NP scenario.

Establishment of the rural electrification fund (REF) and guarantee to receive at least 0.85% of the annual national budget has been considered in *Peru*. Reimbursement of fund over 10 years is the main advantages of REF. 25% of the revenue raised by the privatization of electricity companies and 100% of the total sanctions are external sources of funding. External debt provided 70% of electrification budget by 2003. Debt as a more significant funding system for the predicted future is considered [1]. According to the literatures, two different financial approaches in electrification policy of *Peru*, are in contrast: the need for increased national funding, and the success of individual projects tend to be considered separately. These different approaches make a gap between the national government's budget and ITDG's budget. A future policy has to take into account the total benefits of each small and large distribution firms in term of cost and advantages. Various parameters influence the per-unit cost and affect the better usage of total budget, include more focus to select the better project, and combination the private sector's and communities' investment [1].

Equity became more significant whereas subsidies and loans reduced the total cost of projects in *Nepal*. Remittances could play a remarkable role in the electrification procedure in the case that global financial crisis would decrease the pace of rural electrification in *Nepal*. The highest load exposure was allocated to small hydro projects (62%). It followed by solar photovoltaic (21%), biomass (13%) and micro-hydro (4%). 37% of all rural electrification loans and 98% of the loans in micro/mini hydro, solar photovoltaic, and biogas are supplied by Agriculture Development Bank (ADB) and Rastriya Banijya Bank (NBB, National Commercial Bank) that are owned by the government of *Nepal* [24].

The total investment for the rural electrification program in *Thailand* between 1997 and 2001 was US$429.3 million. As a result, 2.7 million rural residential (88% of people whom were under poverty line) were electrified by the end of 2001. Despite the project was not financially viable, it was economically viable and with the consideration of social and environmental benefits, the internal rate of the economic analysis was around 13% [67]. Financial mechanism systems in *Fiji* are mostly based on fee-for-service. The households pay US$14 monthly for operation and other supportive costs. This tariff does cover the initial capital cost of the system, which the government of *Fiji* financed [2].

Financial assistance in *Kenya*, as in most developing countries, is divided in to two categories. The first group is known as the private and international companies that mostly invest on grid electricity expansion. Another funds are related to government or organizations that are working under the control of government, which pay the renewable energies projects [13,49,53,68,69]. *Malawi* rural electrification program with the main aim of grid electrification expansion to the several villages uses approximately US$ 4.5 million from an international companies [51]. There are indeed several financial institutions having recently re-engaged in the power sector in *Rwanda*, in particular institutes like WB, EU institution, African development bank, Nordic development bank and Swedish companies. The universal access fund can be financed by multiple funding sources, including international donor funds [51,52].

Several companies include government agencies manage the financial problems of the rural electrification projects in *Tanzania*. The main parts of technical assistance are made by different companies that are working under the government. Although, there is no financial assistance from the government, the technical assistance can have a properly effect on the improvement of the project. Like many other African countries, same funds are exported to *Ethiopia*. These funds are used to improve the projects, which are operating on renewable energy sources in villages [51].

In *Zambia*, all of the finances are focused on hydropower project in rural area. Financial assistance are mostly from WB, Arab Bank and government's agency manage by the companies that work under the government [28,51,70]. Other international banks and companies are: Africa continent like, Economic Community of West African States and Commission Economic Monitoring Africa Center institute [70]. These regional organizations are listed in Table 5.

## 4. Implemented projects based on the policies

The use of different energy sources for rural electrification development in different countries were taken into account. Availability, cost effectiveness, financial support, implementation

**Table 4**
Additional financing for electricity access in the Energy for All case scenario compared with the NP Scenario [3].

| | Annual Investment (US$ billions) | People gaining access annually (million) | Level of household energy expenditure | Main source of financing | Other sources of financing |
|---|---|---|---|---|---|
| On-grid | 11.0 | 20 | Higher | Private sector | Developing country utilities |
| | | | Lower | Government budget | Developing country utilities |
| Mini-grid | 12.2 | 19 | Higher | Government budget, Private sector | Multilateral and bilateral guarantees |
| | | | Lower | Government budget | Multilateral and bilateral concessional loans |
| Off-grid | 7.4 | 10 | Higher | Multilateral and bilateral guarantees and concessional loans | Government budget, Private sector |
| | | | Lower | Multilateral and bilateral concessional loans and grants | Government budget |

barriers, and feasibility are the main reasons to choose different power sources by different countries. Table 6 indicates the reasons of using different power sources for electrification in different countries.

Generally, there are two approaches for rural electrification including extension and compaction of the central grid and implementation of local stand-alone systems. According to the conditions of rural areas, the stand-alone system is the most appropriate if the grid extension is not feasible and economic [71].

Based on the electricity production technologies, different systems are available and applicable for rural electrification. By improving technology, increasing environmental concern, and lack of fossil fuel sources, the applied technologies changed from traditional thermal power plant using fossil fuels to renewable energy technologies like solar, wind, hydro, biomass, and wave. Nuclear source is a disputed topic due to being unfriendly to environment and human. The combination of renewable powers such as PV or wind with a fossil fuel provides more energy on demand. Thus, by altering the power sources to renewable energy resources, electricity will be available in different natural condition such as island, plain areas, mountains, etc. [74]. The overview of electricity generation in the world based on the power source is tabulated in Table 7.

**Table 5**
Investment requirements for increasing access to modern electricity in sub-Sahara [70].

| Name of Bank/ Company | Loan | Remarks |
|---|---|---|
| World Bank | 14 (US$ billions) | 48% by 2030 (725 million people) |
| ECOWAS | 5.2 (US$ billions) | 50% by 2015 (250 million people) |
| EAC | 0.3 (US$ billions) | 50% by 2015 (110 million people) |
| CEMAC | 0.2 (US$ billions) | 50% by 2015 (35 million people) |

### 4.1. Grid connection

Grid connected electricity, compared with independent electricity generators or off-grid renewable energy technologies, with simplify maintenance, billing, and tariff collection is a common method of electricity distribution in urban and pre-urban areas. Although grid connection is not the economic efficient method to reduce poverty, extending grid connection to the rural area is also depend on distance from grid, topography and the service quality of the existing network [13].

For instance, the government expanded the grid connected electricity in *Malawi*. The lines provide e electricity in the hospital, schools and homes for different rural areas. The populations who are deprived of the high voltage line or transformers were obliged to pay installation expenses. It is worth to mention that some rural residents do not have access to power since they are not capable of paying the side costs [51].

### 4.2. Off-grid systems

The stand-alone or off-grid systems are the best choice of rural electrification when expanding the grid-connected electricity is not feasible. ESMAP and ITDG reported that off-grid system is the cheapest option in many rural areas of *Peru*. They also observed that small-scale private management firms can help the projects to be more economical and socially sustainable [1]. Off-grid renewable energy systems are more expensive, less reliable and more limited with regard the range of energy services in comparison with conventional generators [72,76,77]. However, several renewable energy technologies like biogas digesters, biomass gasifiers and micro-hydro plants are cheaper than diesel generators. On the other hand, fuel supply difficulties and more GHG emission are the most important problems of using diesel generators. Ignoring the initial cost, low carbon (renewable) off-grid technologies are the best electrification option in rural areas from the environmental point of view [13].

**Table 6**
Reasons and policy of using different power sources for electrification in different countries.

| Power source | Sample of countries | Reason, policy or goals | Ref. |
|---|---|---|---|
| Grid connection | Malawi | Having enough funds to provide grid facility<br>Not having high renewable energy potential<br>Schools, hospitals and medical centres are the most important place to provide electricity | [13,51] |
| Off grid | Peru | Helping to small scale projects for small firms<br>It's cheaper than grid connection | [1,71,72] |
| Mini/micro-grid | Burkina Faso & Kenya | To provide:<br>Telecommunication<br>Health<br>Drinking water<br>Lightning service | [51] |
| Solar panel | Bangladesh | Its price cheaper than rest of fuel sources like kerosene.<br>In period of 5 years poverty reduction reached from 5.4% to 16.7% | [12,40] |
| Solar system | Fiji | Reduction maintenance cost<br>Overcoming tamper<br>reclining overexploitation | [2] |
| Bio mass | Bangladesh | Usage Bio mass stove in decreasing the energy poverty | [40] |
| Micro-hydro | Bolivia | Having many rivers has a huge potential that are known as highest benefit | [71] |
| Solar panel & hydro | Nepal | Increase delivery efficiency in rural regions<br>Subsequently to enhance the access of lower income households | [24,73] |
| Hydro power plant | Uganda | High portion of electricity is produced by hydropower with a total output of 380 MW<br>17 MW grid connected electricity were generated in 2007 by small hydro power plants. | [51] |
| Wind | Turkey | Energy production is equivalent of 73 ktoe in 2008<br>The Capacity of electricity reached a level of 94 GW in 2007 | [21] |

**Table 7**
World net electricity generation based on power source, most recent annual estimates, 2009 [75].

| Country | Billion kW h | | | | Total |
|---|---|---|---|---|---|
| | Conventional thermal | Hydroelectric | Nuclear | Geothermal, solar, wind, wood and waste | |
| Canada | 129.19 | 360.21 | 85.90 | 10.80 | 586.10 |
| Mexico | 200.91 | 26.45 | 9.98 | 9.58 | 246.92 |
| United States | 2726.45 | 273.45 | 798.86 | 156.21 | 3954.96 |
| North America | 3057.60 | 660.10 | 894.73 | 176.58 | 4789.02 |
| Argentina | 73.46 | 33.50 | 7.75 | 1.64 | 116.34 |
| Bolivia | 3.53 | 2.27 | 0.00 | 0.06 | 5.87 |
| Brazil | 35.52 | 387.08 | 12.31 | 23.18 | 458.09 |
| Chile | 29.12 | 25.04 | 0.00 | 4.14 | 58.30 |
| Colombia | 14.59 | 40.64 | 0.00 | 0.63 | 55.86 |
| Cuba | 16.52 | 0.15 | 0.00 | 0.51 | 17.18 |
| Nicaragua | 2.49 | 0.29 | 0.00 | 0.58 | 3.36 |
| Peru | 12.08 | 20.17 | 0.00 | 0.47 | 32.72 |
| Central & South America | 297.01 | 684.17 | 20.06 | 36.77 | 1038.02 |
| Belgium | 33.59 | 0.33 | 44.86 | 6.10 | 84.88 |
| Denmark | 24.06 | 0.02 | 0.00 | 10.21 | 34.29 |
| Finland | 24.67 | 12.56 | 22.35 | 8.77 | 68.35 |
| France | 52.54 | 56.57 | 389.25 | 13.92 | 512.27 |
| Germany | 324.92 | 18.47 | 128.19 | 76.76 | 548.33 |
| Greece | 49.72 | 5.32 | 0.00 | 2.65 | 57.68 |
| Italy | 203.63 | 48.65 | 0.00 | 21.42 | 273.70 |
| Netherlands | 90.99 | 0.10 | 4.02 | 11.79 | 106.90 |
| Norway | 4.11 | 124.89 | 0.00 | 1.23 | 130.22 |
| Poland | 133.67 | 2.35 | 0.00 | 6.21 | 142.24 |
| Portugal | 29.04 | 8.20 | 0.00 | 9.79 | 47.03 |
| Romania | 28.19 | 15.56 | 11.16 | 0.03 | 54.94 |
| Spain | 153.77 | 26.07 | 50.12 | 45.64 | 275.60 |
| Sweden | 3.65 | 65.19 | 49.56 | 13.95 | 132.36 |
| Switzerland | 0.74 | 35.37 | 26.30 | 2.37 | 64.77 |
| Turkey | 147.19 | 35.60 | 0.00 | 2.13 | 184.92 |
| UK | 259.32 | 5.21 | 65.64 | 20.66 | 350.83 |
| Europe | 1755.99 | 560.06 | 865.29 | 274.47 | 3455.81 |
| Bahrain | 11.33 | 0.00 | 0.00 | 0.00 | 11.34 |
| Iran | 205.48 | 7.15 | 0.00 | 0.22 | 212.84 |
| Iraq | 40.27 | 0.51 | 0.00 | 0.00 | 40.78 |
| Saudi Arabia | 204.06 | 0.00 | 0.00 | 0.00 | 204.06 |
| Syria | 38.96 | 1.91 | 0.00 | 0.00 | 40.86 |
| UAE | 85.14 | 0.00 | 0.00 | 0.01 | 85.15 |
| Yemen | 6.34 | 0.00 | 0.00 | 0.00 | 6.34 |
| Middle East | 755.85 | 10.26 | 0.00 | 0.31 | 766.42 |
| Botswana | 0.42 | 0.00 | 0.00 | 0.00 | 0.42 |
| Ethiopia | 0.48 | 3.55 | 0.00 | 0.01 | 4.04 |
| Madagascar | 0.65 | 0.70 | 0.00 | 0.00 | 1.35 |
| Mozambique | 0.01 | 16.78 | 0.00 | 0.00 | 16.79 |
| South Africa | 218.31 | 1.44 | 13.00 | 0.30 | 233.05 |
| Tanzania | 1.73 | 2.76 | 0.00 | 0.00 | 4.49 |
| Zambia | 0.03 | 10.17 | 0.00 | 0.00 | 10.20 |
| Zimbabwe | 3.46 | 4.16 | 0.00 | 0.00 | 7.62 |
| Africa | 483.92 | 97.68 | 13.00 | 4.26 | 598.86 |
| Afghanistan | 0.28 | 0.63 | 0.00 | 0.00 | 0.91 |
| Australia | 227.32 | 12.11 | 0.00 | 6.48 | 245.90 |
| Bangladesh | 34.13 | 1.54 | 0.00 | 0.03 | 35.70 |
| Cambodia | 1.08 | 0.05 | 0.00 | 0.01 | 1.14 |
| China | 2802.52 | 548.96 | 66.60 | 27.65 | 3445.72 |
| Fiji | 0.31 | 0.46 | 0.00 | 0.04 | 0.81 |
| India | 708.66 | 105.84 | 14.01 | 18.93 | 847.43 |
| Indonesia | 126.71 | 11.27 | 0.00 | 8.89 | 146.86 |
| Japan | 616.65 | 74.44 | 265.76 | 28.53 | 985.38 |
| Korea, North | 8.11 | 12.34 | 0.00 | 0.00 | 20.45 |
| Korea, South | 281.02 | 2.79 | 140.38 | 1.95 | 426.13 |
| Malaysia | 92.51 | 6.60 | 0.00 | 0.00 | 99.11 |
| Nepal | 0.01 | 3.08 | 0.00 | 0.00 | 3.09 |
| New Zealand | 11.54 | 23.98 | 0.00 | 6.57 | 42.09 |
| Pakistan | 60.55 | 27.81 | 2.51 | 0.01 | 90.88 |
| Thailand | 127.13 | 7.08 | 0.00 | 5.61 | 139.82 |
| Vietnam | 50.02 | 29.68 | 0.00 | 0.01 | 79.71 |
| Asia & Oceania | 5452.63 | 901.80 | 529.23 | 119.06 | 7002.72 |
| World total | 12,671.47 | 3145.17 | 2568.72 | 615.42 | 19,000.78 |

*Burkina Faso* and *Kenya* are the countries that are concentrating on off grid systems specially the solar technologies. The government also imported 124 GWh electricity from Ivory Coast and Ghana in 2007. According to the government's report, around 460 kW of required electricity for telecommunication, health, water and lighting services are provided by PV systems in the rural area [51].

#### 4.2.1. Mini/micro-grids

Decentralized diesel generator as a kind of microgrid provides electricity normally just for few hours a day. This kind of small-scale grid is normally supported by the local authority, the payment for individual consumer according to the number of electric equipment. Therefore, payment is not based on the real consumption and is above the tariffs of the electricity utilities company in the grid-connected area [14].

Fuel supply problem, high operational cost, and producing emission using hydrocarbon fuels lead to use available renewable energy sources to electrify the rural areas. Off-grid photovoltaic technologies are applied in rural areas through the single and collective systems based on the number of households, grid length, and load demand. Single system includes individual PV array, batteries and loads, which will be explained in next section. Collective system as a micro-off-grid system is more suitable for small medium villages. This system generates centralized electricity and distributes electricity by a small grid. Diesel generator can be added to the system as a back-up [74,78–80]. The effect of overconsumption from one or some users to the village is a common problem of collective systems to compare with individual system that can be managed by users [78].

#### 4.2.2. Solar (stand-alone systems, battery charging stations)

As discussed earlier, different countries use a variety of methods, models and policies in order to electrify remote region existing in urban and suburban. *Bangladesh*'s government established about 500,000 SHS during a few years [12]. The program at *Fiji* was accompanied and helped by Japan, started in 2002 and finished in 2005. The systems established in the project were all in the same size of 100 Wp having five lights and also total number of 250 systems have been sold under the project [2]. It is estimated by The WB that between 1982 and 1997, approximately 5000 systems (differing from 300 to 700 USD for each single system) were sold via different small PV businesses in *Sri Lanka* [33].

#### 4.2.3. Biomass gasification

Investigating the *Bangladesh* strategies for electrifying the rural areas determine the prominent role biomass stoves in decreasing the energy poverty. Whereas electricity promotion is highly significant in this country, biomass has certain advantages in rural areas [12]. The total potential recoverable bio-energy in *Turkey* is estimated to be around 16.92 Mtoe and the production of biomass energy is around 6.98 Mtoe in 2001 [21].

#### 4.2.4. Hydro

Natural resources and structure of each place are the most important factors to choose the proper kind of renewable energy with highest benefits. Despite rivers are barriers in access to the rural areas, it may be possible to get hydro energy from them to produce electricity. *Bolivia* as a country surrounded by many rivers has a huge potential to implement Micro-Hydro Power (MHP) [71].

The MHP and solar PV are mostly used in the rural area for electrification in *Nepal*. An average of 540 kW/yr for MHP and 110 kW/yr for PV cells were installed before the subsidy policy in 2000. These amounts have increased to 760 kW/yr for MHP and 400 kW/yr for solar PV right after implementing the subsidy policy. By another program, *Nepal*'s government has also introduced a program to use solar PV and micro-hydro to provide a capacity of 20 MW from 2007 to 2011 to serve 300,000 households [24,73]. The *Turkish* government desires to expand the hydroelectric power plant capacity to 35,000 MW by 2020. The total generated electricity from the potential hydro power plants under construction at various stages is estimated to be 27,696 GW h/yr [21].

Since, the potential of hydro energy is so high in *Rwanda*, the main aim of the government is development of micro-hydro power to generate electricity. Now, 53% of total electricity in Rwanda is generated by renewable energy [13]. The main strategy for improvement of the rural electrification in *Uganda* is based on the hydropower systems with an output around 400 MW. According to the governments' report, high portion of electricity is produced by hydropower with a total output of 380 MW. In addition, 17 MW grid connected electricity were generated in 2007 by small hydro power plants. The next goal is expansion of hydropower system for the rural areas [51].

#### 4.2.5. Wind

Nowadays, wind energy as a clean, efficient and cost effective energy source is taken into account. The usable wind energy is estimated to be 8000 MW in *Turkey*. Wind energy has move forwarded significantly over the last two decades. The European Wind Energy Association has evaluated the electricity demand from wind power can cover 20% of total electricity demand in Turkey. Energy production from wind is equivalent of 73 ktoe in 2008 in Turkey. The total installed wind power capacity in worldwide, with an average annual growth rate from 8 to 94 GW, reached a level of 94 GW in 2007 [21].

#### 4.2.6. Wave

To generate a substantial amount of power, wave energy converters (WECs) are arranged. The WD-WEC is a floating offshore converter of the overtopping type, which captures the water volume of overtopped waves in a basin above mean sea level and produces power when the water drains back to the sea through hydro turbines. WD-WECs arranged in a single line produce the highest amount of power, but requires an available sea area with a large width (51 km) [81]. The Pelamis floaters, produced by Ocean Power Delivery Ltd, is a kind of wave energy converter for generating electricity from marine waves, can generate 0.75 MW with a 120 m long device. Floating Power Plant which is designed to produce 10 MW (56% from waves and 44% from three windmills) is an example of hybrid (wave–wind) system to produce electricity [82]. A nested computational grid along the major Hawaiian Islands in the global *Wave Watch 3* (WW3) model implemented in Hawaii region. While the episodic swell events have enormous power reaching 60 kW/m, the wind waves resources power can be 15–25 kW/m throughout the year [83].

## 5. Barriers and issues

The complexity of the project implementation process has challenged countries to develop their weakness to overcome into the barriers and issues. However, understanding how to overcome the barriers, delays and disincentives associated with implemented projects and policies are taken into account as a road map for the future projects and policies. Shown in Table 8 is the summary of different barriers and issues associated with rural electrification projects with some factors that affect to cause barriers and their impact on society.

Grid extension to the rural areas is faced with difficulties such as extensive geographical area with dispersed communities and low electricity demand, which leads to an enhancement in installation cost. Despite of low GHG emission, electrification with renewable energies is involved with various kind of barriers and issues explained in this section. Generally, the challenges can be classified into economic, legal, financial and institutional.

**Table 8**
Barriers and issues associated with rural electrification and their impacts.

| Barriers and issues | Factors | Caused to | Ref. |
|---|---|---|---|
| Economic barriers | Lack of subsides<br>High initial capital cost<br>High transaction costs | Not attention to low population density area<br>that much expensive<br>technical standards and the tariffs for rural<br>resident Usage candle,<br>scavenged wood or biomass | [2,68,84] |
| Not willing for companies & investors | RE is known as new business<br>Having high risk<br>Spending substantially money | Not creating new technical job<br>Not improving RE in whole area | [49] |
| Insufficient technical knowledge | Lack of detailed RE resource assessment<br>Lack of financial data<br>Lack of financial support | Migration to countryside<br>Not improving RE in whole area | [21,67] |
| Inefficient legal environment | Road Natural barriers (mountain, river)<br><br>Climate barriers | Delay to provide technical tools facility<br>Delay to provide human resource<br>Financial damage for supplier and projects companies | [14,58] |
| Insufficient public awareness | No information about maintenance and service given after sale<br>Wrong management | Lose the faith by consumers<br>Making projects unreliable for users<br>Economic damage | [2,62,85] |

**Table 9**
Challenges of renewable energies and electrification development.

| Economic | Lack of pricing policies, financing concerns |
|---|---|
| Legal and regulatory | Short leash syndrome, lack of statics data, institutional structure, policy and regulatory framework, monitoring and evaluation framework |
| Financial and institution | Institutional structure, access issues |

The challenges facing the electrification development are listed in Table 9.

Electricity production, as one of the main parts of modern life, become more centralized to increase efficiency, feasibility, and durability along with issues such as dispersed low-income consumers and low demand of electricity in rural areas. Infrastructures such as roads, commercial availability of equipment and financial sources play significant role in promoting the rural electrification. In some places, accessibility to the rural areas is limited to the seaways by boat. The consolidated technological option for these cases is using decentralized generator, which is more expensive with more difficulties to supply the fuel [14].

The economic barriers include lack of subsidies in renewable energies, high initial capital cost, in failure to incorporate future fuel cost risks for fossil fuel, high transaction costs for small decentralized system, and lack of rational pricing policies [2]. According to the conducted research in university of *Botswana* in 2006 [86], the rural area that has the high populating density will be able to use national electricity grid because high populating density reduces the overall costs of electricity distribution network within such community. In general, in many cases where electricity is available, expensive technical standards and the tariffs made electricity distribution of the utilities and electrical energy are too expensive. Instead of using electricity poor households may use scavenged wood and biomass since they cannot spend much on energy and the appliances [11]. Households only use candles for back-up purposes in case of electricity failure or insufficient money to purchase pre-paid electricity cards [68]. Most of the poor households, who live in an adobe hut, do not have electricity, and tend to use paraffin for lightening [84].

When it comes to barriers and issues, many problems can be considered for rural electrification. Some problems are related to companies and investors who do not invest because electrification was the new business and has high risk. Besides, skilled workers would not be willing to work in the rural areas unless they get a substantially greater pay and special benefits. These issues are the main factors that cause companies not to get the high risk for improving rural electrification [49].

Factors such as insufficient incentive of private section, governments' investment in projects, elimination of poverty, creating progress in rural areas, mitigation of the migration from countryside to city are to be considered when it comes to electrification in *China* and other areas [67]. Lack of detailed RE resource assessment and data banks, lack of financial support, accurate proposing facilities particularly for small-scale programs are the major limitations in *Turkey*. Awareness increasing is yet a key to involve specifically the community based and non-governmental organizations [21].

Lack of statistical data on electricity consumers and suppliers and business cost for project development, operation, maintenance overall profitability, are the main barriers of developing projects in *Cambodia* that can be solved by sufficient time and money. Other issues like inefficient legal environment in which the laws are awaited to be approved exacerbates the weak regulatory framework in *Cambodia* that can lead to lack of clear division of the responsibilities between the energy companies and financing institutions. The high initial cost of RE systems due to the high import tax (35%) and the high electricity price can be pointed out as the main problems of rural consumers and lack of favorable investment environment and loan systems for the energy provider are known as the main issues for energy providers [87].

For *Fiji* the maintenance and services given after the sale are the major problems that make projects unreliable for the users and cause the customer to lose the faith in such programs. The isolated nation and scattered arrangement cause high cost of social service delivery and rural development. Maintenance costs may be decreased through preparing accurate trainings on the usage of the system. Consultation with the community on the progression of the program, management is essential in order to make a sense of ownership among consumers. Government support can also accelerate the improvement of the program [2,88].

For the case of *Thailand*, finding a balance between market-pull (on account of demanded productions, assessment of willingness to pay, availability of credit, after sales service network, etc.) and

donor-push strategies (in terms of R&D support, fiscal and financial incentives, simplified procedures, etc.) continues to be a challenge as both seem to have primed the decentralized PV markets across the world and continue to do so even at the present time. Some factors related to consumers such as alertness, training project, active attendance in decision making, and recognizing socio-economic benefits of PV systems are also important [89]. Unlike the money that households spend for electricity, it is to some extent cheaper than that of kerosene in *Bangladesh*. A transition of the power supplement from kerosene to electricity can be postponed by the inaccessibility of electricity in the community and the high price of household connection [12].

Small-scale hydro plants face to the number of barriers in *Sweden* and *Norway* including uncertainty about future revenues, financial support, selling power to the grid, complicated regulations, large number of stakeholders, and the required technical competence [46].

Lack of high voltage transmission and distribution grids, lack of interconnection between regional grids and wrong management of existing power plants can also be considered as the main barriers in the *Africa* continent [85]. According to the conducted research by the development research group in the WB [62], the tariff of solar photovoltaic generated electricity is 2–3 times more than grid electricity, it varies from 66 cents/kW h to more than one dollar. The research conducted in *Ethiopia* by the Ministry of Economic Development in Addis baba [49] shows that the rural households which were provided with diesel motors, for using only 3 h a day of three 60-W bulb, the amount charged is 2 USD. It can be said that, providing electricity by the diesel and motors for rural areas with low population density is expensive for the local people [84].

In *Peru*, lack of competitive, appropriate project selection, shortage and uncertainty of funds, and opportunities for corruption hampered the rural electrification projects under the Rural Electrification Plan (REP) [1]. The concession can help to create a market with sustainable business in a large geographical area. But the problem is the lack of sufficient bidders to make a process competitive [90].

To sum up, the major role of the government becomes eminent in making the policy. Moreover, the responsibility of government in assuring the framework of the renewable energies affects the expansion of services to rural areas. Companies also have to be in a special situation to recoup their investment. Since renewable energies faced with the issues of poverty, profitability of utilities and environmental considerations, it is quite evident that governments need to formulate policies that incorporate incentives for both private and public utilities to engage in renewable energy [28].

## 6. Conclusion

According to the IEA report, emphasizes on electrification of areas with less access to electricity have to be considered as a serious issue. In this regard, Sub-Sahara Africa with the lowest level of electrification in the world should be of more concerns for international and local policy makers. Renewable resources should be taken into account in almost all aspects of the future global policies. Therefore, sustainable development under the sponsorship of renewable resources must be considered as an achievable target. Furthermore, global policy approaches to reduce the GHGs and the effect of fossil fuels on environment must force countries to turn to renewable energy sources. Formulating the general policies relating on energy and particularly on rural electrification would increase efficiency of subsystems considerably. The link between government, local and private communities is a key challenge on rural electrification policies. The most successful projects are those that support job creation and have a direct effect on income of the local people. Last but not least, increasing consumer level of education and awareness can enhance the project.

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